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ABSTRACT

In order to take into account in a more productive, effective manner children's prior science knowledge in the development of science curricula and in the teaching of science, it is important "to know how to explore it, to know about its nature, and to consider the various ways it may, or may not be modified" (Gilbert, Osborne, and Fensham, 1982). Given that many elementary teachers report feeling either ill-prepared or unqualified to teach science, the experience of elementary school students in learning science particularly warrants continued investigation. This study attempts to take a step beyond identification of preservice elementary teachers' science misconceptions in the direction of concurrent characterization of the bases of these ideas. Using a multi-step process of development, revision and validation, an 11-item multiple-choice test exploring the concepts of surface area/volume and states of matter was developed for subsequent use in evaluating and revising a science process skills course for preservice elementary teachers. Each of the items in the test included a description of situation, a multiple-choice question based on the situation, followed by eight to twenty possible explanations for the answer selected. Test results allow the researcher to identify pre-knowledge about the concepts of interest and to characterize the degree of congruence between the learner's school and intuitive sources of knowledge. It is proposed that this and similar concepts tests could be used in evaluating the effectiveness of strategies devised to change misconceptions or to bring learners' school and intuitive knowledge into congruence with other measures of ability or pre-knowledge to explore interactions with different methods of instruction. Sample questions are appended. (Author)

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THE DESIGN AND VALIDATION OF AN INSTRUMENT TO IDENTIFY PRESERVICE ELEMENTARY TEACHERS' INTUITIVE AND SCHOOL KNOWLEDGE OF THE CONCEPTS OF SURFACE AREA/VOLUME AND STATES OF MATTER

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Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Lake Geneva, Wisconsin, April 7-10, 1991.

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ABSTRACT

In order to take into account in a more productive, effective manner children's prior science knowledge in the development of science curricula and in the teaching of science, it is important for us "to know how to explore it, to know about its nature, and to consider the various ways [it] may, or may not be modified" (Gilbert, Osborne, and Fensham, 1982). Given that many elementary teachers report feeling either ill-prepared or unqualified to teach science, the experience of this group of students in learning science particularly warrants continued investigation.

This study attempts to take a step beyond identification of preservice elementary teachers' science misconceptions in the direction of concurrent characterization of the bases of these ideas. Using a multi-step process of development, revision and validation, an eleven item multiple-choice test exploring the concepts of surface area/volume and states of matter was developed for subsequent use in evaluating and revising a science process skills course for preservice elementary teachers. Each of the items in the test included a description of a situation, a multiple choice question based on the situation followed by eight to twenty possible explanations for the answer selected. The explanations included correct, incorrect and intuitive and school knowledge items. Test results allow the researcher to identify pre-knowledge about the concepts of interest and to characterize the degree of congruence between the learner's "school" and "intuitive" sources of knowledge. Reliability of the SVSM Concept Test determined for preservice elementary student was 0.94 (Cronbach's alpha).

It is proposed that this and similar concepts tests could be used in evaluating the effectiveness of strategies devised to change misconceptions or to bring learners' school and intuitive knowledge into congruence; in conjunction with other measures in evaluating conceptual change; and with other measures of ability or pre-knowledge to explore interactions with different methods of instruction.

Introduction

Over the past several years increased attention has been paid to the role of learners' pre-knowledge in the creation of knowledge. Gilbert, Osborne, and Fensham (1982) point out that if children's prior science knowledge is to be taken into account in designing curricula and in teaching science,

> it will be necessary for us to learn much more about children's science: to know how to explore it, to know about its nature, and to consider the various ways in which children's science may, or may not, be modified by learning experiences. (p. 624)

Perhaps in keeping with this point of view, the number of investigations of learners' preconceptions and the impact of prior knowledge upon the learning situation has increased. A variety of procedures, most involving in-depth interviews (Gilbert, Osborne, and Fensham, 1982), have been developed.

While the origins of childrens' science are quite varied (see, for example, Osborne and Freyberg, 1985), a significant portion of this pre-knowledge, whether correct or incorrect, is either intuitively derived from daily experience or learned in school. West and Pines (1985) have labeled these two particular sources as either "intuitive knowledge" or "school knowledge" and have suggested that the ideal teaching situation is when both intuitive and school knowledge are extensive and congruent.

Purpose

The purpose of this study was, therefore, to develop an instrument which would accomplish two things: 1) the identification of preservice elementary teachers' pre-knowledge relative to two concept areas and, 2) the characterization of these ideas as either "intuitive" or "school" knowledge. This information could subsequently be used

to assess the degree of congruence between students' intuitive and school knowledge and to improve instruction in the two particular concept areas.

Continued research exploring the nature of elementary teachers' pre-knowledge and understanding of science concepts is warranted given that many elementary teachers feel unqualified (Weis, 1978) or ill-prepared (Donnellan, 1982) to teach science. In one such effort, McDonald and Betkouski (1986), designed a multiple choice/true-false test to assess preservice teachers' understanding of the concept of density, pointing out that the identification and correction of misconceptions held by elementary teachers is particularly critical. Therefore, subjects selected for involvement in this study were pre-service elementary teachers.

Two concept areas were chosen for the purposes of the study: surface area/volume and the states of matter. These concepts were selected for several reasons. College students have had an opportunity to develop both intuitive and school knowledge of these concepts and many have difficulty in understanding the concepts. More pragmatically, these concepts are covered in a required science process skills course for preservice elementary teachers. Given these parameters, this particular course provided a context for the development of the instrument and for the subsequent use of the instrument in improving course instruction.

Procedures

The first step in the development of the instrument was the collection of data relative to students' ideas about surface area/volume and states of matter. Given the extensive interview data reported by Osborne and Cosgrove (1983), their study was used as a basis for the development of the states of matter test items. In that study,

students were shown a series of events involving such physical changes as ice melting, water boiling, water condensing on a cool object, or water evaporating. Students were subsequently asked to describe the event observed and to offer an explanation of what had happened. The researchers also used students' comments and ideas reported by instructors in the science process skills course in the development of test items.

To provide a similar data bank for the development of questions about the concepts of surface area/volume, 25 students in the science process skills course were interviewed. In one set of interviews, for example, students were first shown a demonstration such as making a "snake" from a ball of clay and then were asked questions about the volumes and surface areas of the two objects. From these taped interviews, ideas and explanations both correct and incorrect, "school" and "intuitive" were extracted. In addition, information about students' ideas was again collected from several science process skills course instructors.

Based upon these data, an 11-item multiple choice test was developed. The question format included a description of a situation, followed by a multiple choice question about the situation and a list of between eight and twenty possible explanations for the multiple choice answer chosen (see examples, Appendix A). Care was taken to include in the list of explanations both correct and incorrect explanations as well as explanations reflective of "intuitive" and "school" knowledge.

This initial form of the test which included 182 explanations for 11 items was given to four classes of the science skills course. Based on item analysis, the list of explanations was reduced. Items which were poor discriminators or appeared to be

confusing were eliminated. Figures were altered to increase clarity of questions.

A panel of five "experts" were then asked to review the instrument. Each of these individuals was either a science educator with chemistry teaching experience or an experienced high school chemistry teacher. These "experts" were asked to take the test and to indicate for each explanation whether it was correct/incorrect relative to the "correct" answer to the multiple choice question and whether each explanation represented "school" or "intuitive" knowledge of the question. To qualify for inclusion in the test, four of the five experts had to agree on both characterizations of an explanation.

After receiving the results from the "experts," the non-qualifying explanations were eliminated and the test again administered to four classes of the science process skills course. After item analysis, the number of explanations on the test was reduced to a final total of 142. The following semester the reliability of this final form of the instrument was determined by administering the test to four classes of science process skills course (Cronbach's alpha=0.94).

Implications for Teaching and Research

The development of the Surface Area/Volume-States of Matter Concept Test (SVSM) represents an attempt to go a step beyond the identification of misconceptions in the direction of concurrent characterization of the origins of students' misconceptions or pre-knowledge. While the development process was time consuming, there does exist a wealth of interview data relative to a wide range of science concepts which could provide a basis for the development of similar concept tests.

It should be noted that the test may be scored in a variety of ways. This flexibility allows the researcher to extricate various kids of information dependent upon his/her purposes.

Concept tests such as the SVSM could be used in a variety of ways to improve instruction in existing science courses, to develop and assess new science curricula, and to explore conceptual change such as:

1) Pre-testing to evaluate the implications of student "congruence" or "conflict" (West & Pines, 1985) for effective instruction;

2) Pre- and post-testing to evaluate the effectiveness of instruction in changing misconceptions or in bringing student knowledge into congruence;

3) Using concept tests with other measures of student pre-knowledge or ability to assess interactions with different methods of instruction.

4) Pre- and post-testing in conjunction with other strategies to assess conceptual change;

These applications are pertinent not only to preservice elementary teachers but to a wide range of learners in a variety of science courses.

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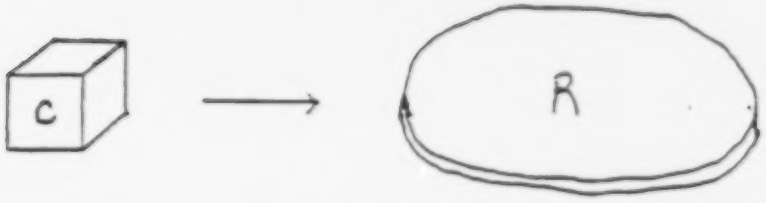
APPENDIX A

Task 4: A cube of clay "C" (8 cm x 8 cm x 8 cm) is reshaped into a flat, rounded pancake "R".



34: Which of the three statements below concerning the volumes of C and R is true?

A. Volume of C is greater than volume of R.

B. Volume of R is greater than volume of C.

C. Volume of C equals volume of R.

Below is a list of possible explanations for your answer to the above question. Mark each statement that is a possible explanation for your answer by blackening the circle labeled (1) on the answer sheet. Blacken (2) for a statement which is not an explanation for your answer.

35. R is thinner and longer than C.
36. The mass of R is less than the mass of C.
37. The amount of space displaced is the same.
38. The product of the area of the base x height is the same for C and R.
39. There is the same amount of clay in C as in R.
40. Both objects could be rolled up into equivalent sized balls.
41. Both objects would displace the same amount of water.
42. C is taller than R.
43. C is more dense than R.
44. Both have the same density.
45. C weighs more than R.
46. C would displace more water than R.
47. R takes up more space.
48. The number of cubic units in C and R is the same.

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APPENDIX A

Question 113: If a cold glass saucer is placed above a kettle of boiling water, after a few minutes you would observe:

A. No noticeable change.

B. Droplets of water forming on the saucer.

C. Droplets of liquid oxygen and hydrogen forming on the saucer.

D. Droplets of steam forming on the saucer.

Below is a list of possible explanations for your answer to the above question. Mark each statement that is a possible explanation for your answer by blackening the circle labeled (1) on the answer sheet. Blacken (2) for a statement which is not an explanation for your answer.

114. Oxygen and hydrogen gases formed during boiling water condense on the cool glass.

115. The oxygen and hydrogen gases formed during the boiling of water slow down on the cool glass and stick together to form water again.

116. The gaseous water from the boiling water slows down and stick to the cool glass forming water.

117. Steam hits the saucer and bounces off the saucer.

118. Hot air slows down when it strikes the cool glass and forms liquid water.

119. The heat rising from the kettle reacts with the coldness of the saucer to form liquid water.

120. The heat rising from the kettle reacts with the coldness of the saucer to form liquid water.

121. Hot steam will not stick to the cool saucer.

122. Heat from the kettle makes the saucer "sweat".

123. Steam carries some water with it from the hot kettle.

124. The steam hits the saucer and softens to form water.

125. Water comes from the steam.

126. Water disappears when it boils.

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